

# **CoBOP Coral Reefs: Optical Closure of a Coral Reef Submarine Light Field**

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## **LONG-TERM GOALS**

Mostly because of the extensive field work during the Coastal Benthic Optical Properties Project at Lee Stocking Island in the Exuma Cays, Bahamas, we have surmised that the traditional problems concerning nutrient regulation of primary production in shallow subtropical benthic communities are poorly understood. Comparative measurements at sites throughout the Bahamas and Florida Keys have suggested that the interaction between nutrient replete deep waters that surround these islands and the porous carbonate platforms provide adjunct avenues of nutrient enrichment. The forces that act to drive this system of nutrient supply are hydrostatic pressure, the earth's rotation and geothermal heating. Our major goal has been to develop a descriptive model of these processes with the end member as predictions of kinetic growth in time and space.

## **OBJECTIVES**

In essence, the Bahama Islands lie in the outer fringes of the North Atlantic Drift current system. As part of this flow, a major transport system passes through the Caribbean Sea and exits through the Florida Straits. It is therefore possible that some of the energy from this transport system provides a mechanism for deep, nutrient rich waters to reach near-surface waters where wind mixing or tidal mixing can transport them onto the benthic reef and grass flats of the region. The COBOP research program provided the opportunity to test this possibility, albeit limited by the lack of seasonal coverage, since we were able to measure oceanographic conditions from the island platform to sea, *i.e.* across Exuma Sound in May of 1998 and 1999. We wish to use this data to confirm our descriptive model of nutrient enrichment and micro- and macroalgal distributions.

## **APPROACH**

In 1965, geologist Hokout proposed calcium carbonate platform, such as the Bahamian complex, for nutrient enrichment of shallow coastal areas. He argued that nutrient rich, deep seawater would intrude through porous limestone and boulder beds at depths where geothermal heating would induce a convective cycle. Nutrient-rich deep seawater would rise along with artesian aquifer freshwater to shallow embayments on the platform. Thus, energy associated with the geostrophic circulation of

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the open ocean would be supplemented with heat from geothermal processes. We used the following reasoning: if the density (isopycnal) surfaces are parallel, *i.e.* density is constant with depth (pressure), and the water mass is termed barotropic, then the possibility of high nutrient/density water being near the surface is not likely. If the density changes are somewhat independent with depth the situation is baroclinic and this independence provides the potential for deep nutrient rich waters to be lifted to shallower depths. Regions where nutrient enrichment occurred could be measured through the photosynthetic efficiency of attached macroalgae and water column microalgae.

## WORK COMPLETED

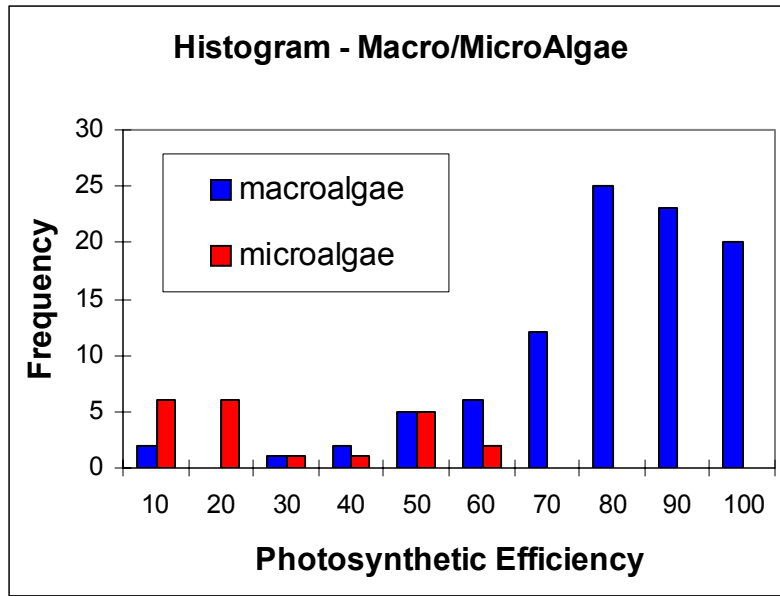
Because the information needed was somewhat outside the original goal set for CoBOP, we have supplemented data gathered within the CoBOP program with data recently collected throughout the Florida Keys and adjacent oligotrophic surface waters of the entire region. This has required the use of measurements of dynamic topography of major currents, coupled with the non-conservative variables such as nitrate nitrogen, ammonia, and phosphate. The growth end member is the ratio of variable fluorescence to maximum fluorescence (Fv/Fm) measured on micro- and macroalgae from the region. In the broadest sense, we compared the algal measurements regionally and interpreted the findings in terms of the physical/chemical factors of the water masses surrounding the islands. A considerable amount of the oceanographic data used is historical, however, to establish nutrient/growth relationships have assembled over 100 measurements of fluorescence yield (Fv/Fm) from intertidal and subtidal macroalgae, natural populations of nearshore and offshore phytoplankton as well cultures of littoral and offshore species. Some of these measurements are accompanied with optical and nutrient characteristics of site specific regions.

## RESULTS

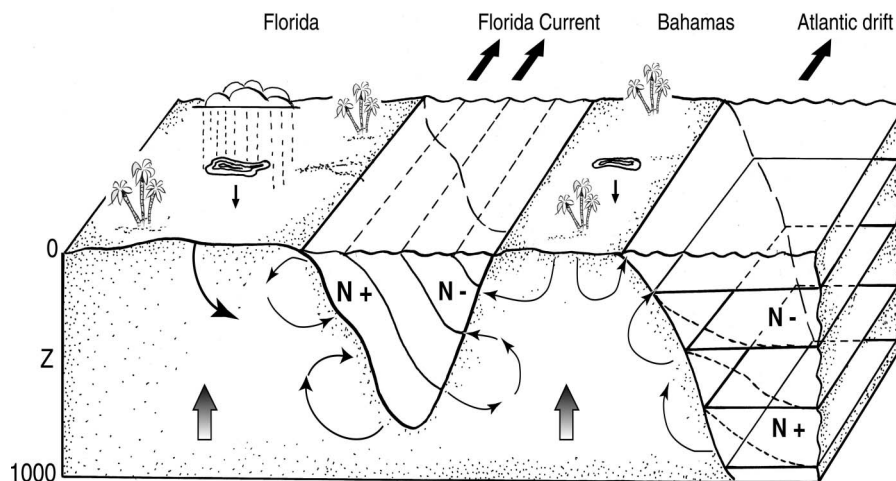
Figure 1 summarizes the frequency of occurrence of photosynthetic efficiencies (as Fv/Fm x 10) for macroalgae and microalgae. The macroalgae have been separated into three color groups: greens, browns and reds. The overall range for Fv/Fm is 0-0.8. The range for the Bahamas/Keys region is 0.1-0.8. The low values (>0.4) are mostly microalgae from the oligotrophic surface waters of the Gulf Stream or Exuma Sound. Most of the high values are from green macrophytes (chlorophytes). The red macroalgae (rhodophytes) had the lowest values with browns (phaeophytes) somewhat intermediate. In the terms of two regions (Bahamas vs Florida Keys) the Fv/Fm values were generally lower in the Bahamas. While the chlorophytes in the Florida Keys consistently registered at or close to the maxima of efficiency, this regional pattern is consistent with the relative abundance of nutrients in each area (higher in the Florida Keys than in the Bahamas) which implies nutrient limitation as the causative factor regulating this distribution pattern.

The mechanism that controls nutrient supply on carbonate platforms, endothermal upwelling, is diagrammed in Figure 2. The influence of ageostrophic flow around the raised platforms causes the density surfaces to lift toward the surface bringing deeper, colder nutrient rich water to a depth where endothermal processes (the earth's heat) can cause upwelling to occur. In the Florida Straits, this occurs at shallower depths than on the Bahamas Bank. Nutrient bearing freshwater, coming down through the porous limestone, encounters the pressure gradient of

seawater moving through the platform. The heat of the earth changes the density of the waters so they flow upward through the limestone rather than out to sea.



**Figure 1.** Frequency histograms of photosynthetic efficiencies of macro- and microalgae measured in the Bahamas and Florida Keys regions. Microalgal efficiencies are all below 5 while macroalgal values range from 1 to 9, with the majority greater than 5.



**Figure 2.** Schematic diagram of the concept of endothermal upwelling from Florida across the Florida Straits, across the Bahamas Bank and out to sea in the Atlantic Ocean. Shaded arrows pointing upward indicate the earth's heat, N+ and N- equate to high and low nutrients, respectively. In the Florida Straits the isopleths of nutrient concentration are slanted upward indicating higher nutrient availability along the eastern Florida coast and low nutrients along the western Bahamas margin.

Is there evidence that geothermal processes occur in the Bahamas? Yes, they are analogous, but the main difference is that the water masses adjacent to the Bahamian platform are barotropic while those

in the Florida Straits are baroclinic. The likelihood of the surface waters being enriched by deep water through conventional geostrophic processes is higher in the latter than the former.

## **IMPACTS AND APPLICATIONS**

The coupling of variable fluorescence measurements of photosynthetic efficiency with physical and chemical variables in ocean water masses has implicated the mechanics of nutrient as a factor controlling the growth of microalgae and microalgae in the Florida Keys and Bahama banks. The interpretation of regional and smaller spatial scale changes argues for a more punctuated theory of nutrient regulation than occurs from seasonal overturn of thermoclines or frontal effects from tides or upwellings. Simply put, in oligotrophic regions, the organisms have to be opportunists. Our studies of variable fluorescence have provided a good index of nutritional status of primary producers in the oceans, perhaps even a surrogate for the f-ratio. We are aware of some of the problems associated with the degree to which Fv/Fm can be interpreted, but are encouraged by the results so far.

## **RELATED PROJECTS**

We have greatly appreciated the many collaborations we have developed throughout the CoBOP program. In this work, we struck out on our own in an area of research that departed from the typical scope of benthic optical properties to investigate causes for the distribution of primary producers in the Florida Keys and Bahamas regions. Dr. Brian Lapointe at Harbor Branch Oceanographic Institution collaborated on one CoBOP cruise, providing analyses that were lacking from the program.

## **PUBLICATIONS**

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